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HYDRO-BIONICS SERVES FLEET

by

A.N. Shmyrev, V.F. Drobilenkov



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*ye initially, after vowels, and after b, b; e elsewhere.
When written as є in Russian, transliterate as yє or є.

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Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	\sinh^{-1}
cos	cos	ch	cosh	arc ch	\cosh^{-1}
tg	tan	th	tanh	arc th	\tanh^{-1}
ctg	cot	cth	coth	arc cth	\coth^{-1}
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

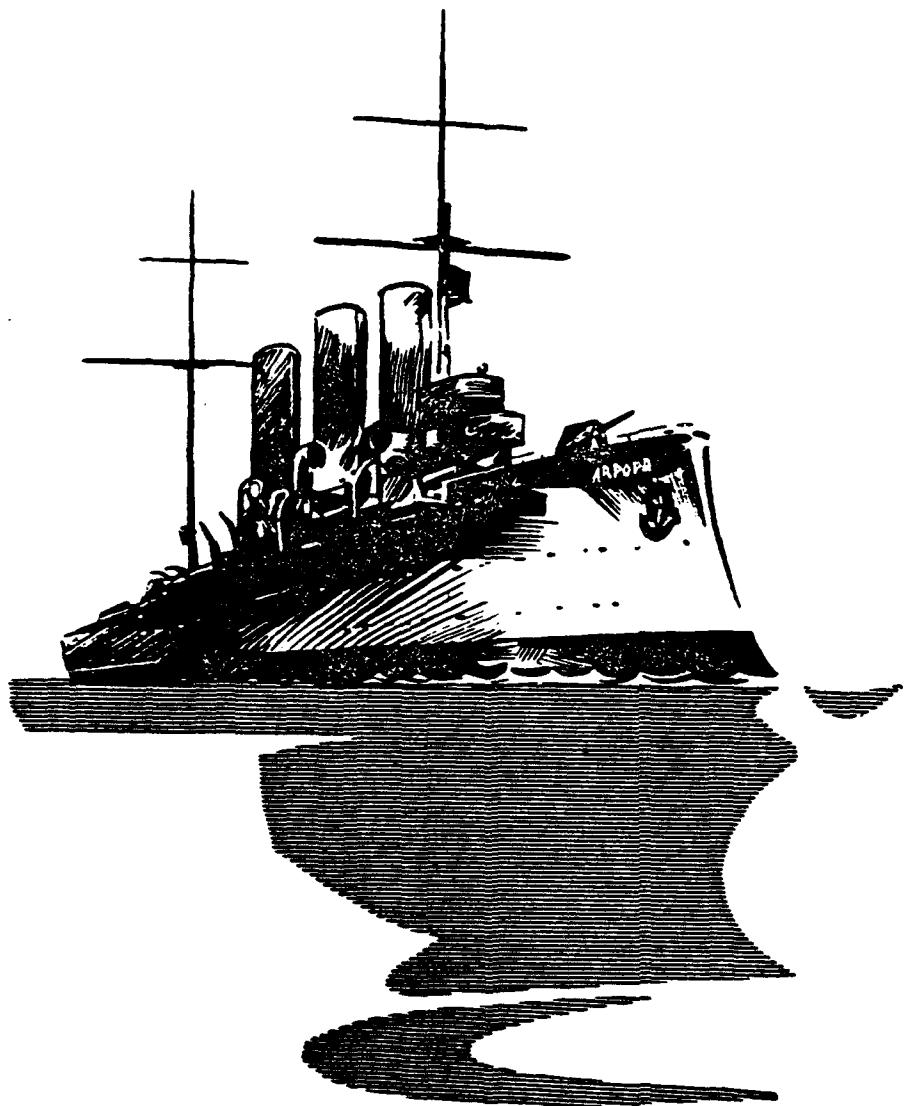
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MARINE HERALD.



Page 32.

HYDRO-BIONICS SERVES FLEET.

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Hydro-bionics - specific region of bionics, which is occupied by the disclosure of hydro-biological laws and by their use in technology, including that connected with ship building, navigation and other aspects of development and activity of fleet. Most important problem of hydro-bionics - to establish and study the analogy between the physicochemical, hydromechanical and information processes, which take place in the organisms, which dwell in the aqueous medium, and in the technical devices. In proportion to the storage of knowledge for the questions indicated becomes possible the creation and the study of the models of hydro-biological processes in the organisms. Moreover investigation on the models do not eliminate, but, on the contrary, are assumed the full-scale investigations of organisms, and also wide theoretical generalizations. Therefore the procedure of scientific works in the hydro-bionics carries the nature of the number of successive approximations.

As the basic trends in development of hydro-bionics are

considered:

development of rational forms and methods of reduction in resistance of bodies to motion in aqueous medium, and also creation of new propeller complexes and ideal controls;

creation of new types of systems of emission, reception, detection, recording and measuring acoustic and other signals, which are spread in aqueous medium;

development of new reliable high speed systems of automatic control and systems of coding, transfer, processing and storing information;

investigation of governing laws and principles of construction of bioenergetic systems of organisms, which dwell in aqueous medium, and systems, which ensure their prolonged deep-water immersion, and also search for ways of technical use of principles of these systems.

Together with basic directions indicated are some quotients, but having sizable value for navigation (for example, connected with orientation, location, camouflage, thermal control in aqueous medium, etc.).

Without having possibility even briefly to throw light on all questions of hydro-bionics, let us pause only at basics.

Optimality of shapes of body for motion in water, reduction in its resistance, effectiveness of organs of motion and control - important problems of ship building. Data on this question can give

the investigations of high-speed fishes and nekton animals (predominantly cetaceous and cephalopods), since it is long ago established that their relative power expenditures for achievement of the corresponding speeds of motion are considerably less than in ships. Thus, porpoise for the motion with the definite speed spends energies almost 7 times less than tow craft for the movement with the same speed of model or frozen small carcass of porpoise.

Page 33.

External structure of fishes is made in essence by development of organs, connected with motion. Therefore even a comparative morphological analysis gives useful information for designing the hulls of ships. For example, Japanese ship-builders attached to the underwater part of the passenger vessel form the geometrically similar to the body of whale, which decreased the resistance approximately by 20%. The test submarine of the USA "Albacore", which served as prototype for the American nuclear powered submarines, in its relationships and enclosures is analogous to the form of porpoise. The profile of the longitudinal section of merma - one of the highest-speed fishes - approaches the laminated profile, found theoretically and experimentally in the aerohydrodynamic laboratories.

Longitudinal section, relationship of main dimensions and shape of body (and, consequently, hydrodynamic characteristics) in majority of fishes depend on mode of life, and in connection with this and from speed of motion. Nature in the process of evolution optimized the

characteristics indicated and is expedient to take them as the standard for the reproduction in the technology.

The hydrodynamic special features of fish nekton animals can be joined into following three large groups.

Scombroides - lamellated, covered with mucus fishes (mermas, pike, perch, sturgeon, etc.), basic propeller/motor in which is horizontally oscillating tail section (Fig. 1a). The high-speed qualities of skombroides are determined mainly by the specific character of their motor-propeller complex and by the presence of the peculiar lubrication, which decreases friction against the medium, and maneuverability - special controls: mobile/motile fins and collapsible stabilizers - fins.

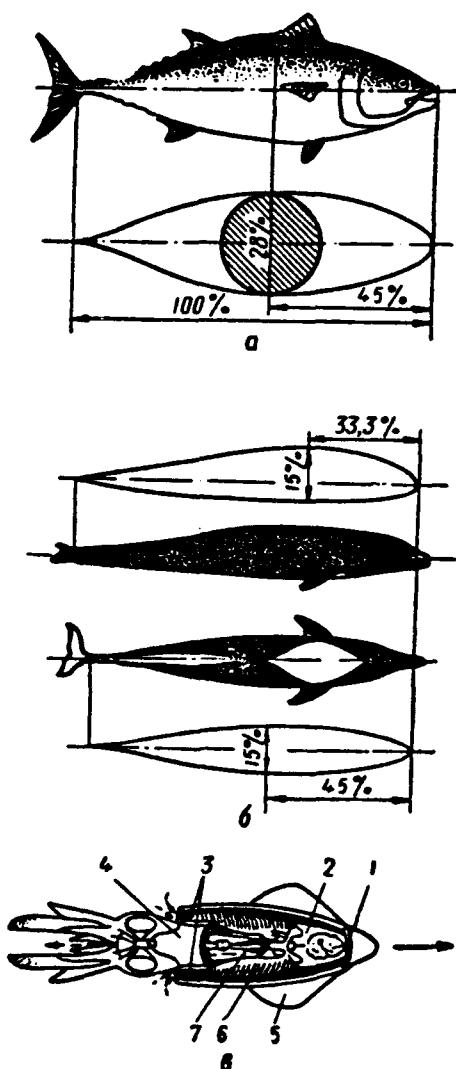


Fig. 1. High-speed marine fishes and animals, that have well streamlined shapes: a) usual merma and its laminated profile (extrapolation); b) porpoise and close to its contours profiles of TsAGI [- Central Institute of Aerohydrodynamics im. N Ye Zhukovskiy] and NASA [- National Aeronautics and Space Administration]; c) squid (1 - mantle; 2 - cavity, periodically filled with water; 3 - cartilages, file closers mantle cavity; 4 - jet nozzle; 5 - collapsible fin; 6 - gills; 7 - ink sack).

Page 34.

Cetaceous - scaleless marine being mammalian (porpoises - whales), propeller/motor in which is vertically oscillating caudal fin (Fig. 1B). Their hydrodynamic special feature (besides the laminated shape of body) - extremely smooth skin, well equipped for damping the turbulent pulsations of liquid in the boundary layer. There is the foundation for assuming that the flow, which flows around about the animals, artificially is laminated because of this "device" of skin.

Mechanism works and characteristic of skin of porpoises are still little investigated. However, in it, probably, there are extremely sensitive receptors of vibrations and pressures, which detect the instability of the state of the flow of water even before in the boundary layer turbulence and turbulent pulsations arise. Such receptors can serve as sensing elements in the systems, which function according to the principle of feedback and regulate the contraction of the muscles, which impart to skin form and elasticity, facilitating damping the incipient eddies of water.

Controls in cetaceous are caudal, thoracic and back fins. Caudal fin, on the essence, not only is propeller, but also "elevator" and the horizontal fin. Thoracic fins correspond to sail elevators on the submarines. Furthermore, accomplishing by them propeller motions, porpoise can slowly rise or lower, retaining horizontal position. Back fin - "keel", which creates if necessary considerable lateral resistances, makes it possible for animal to accomplish sharp

rotations.

Besides functions indicated, back, thoracic and caudal fins participate in heat exchange.

Cephalopods - marine mollusks (squids, octopi, cuttles) have body, in form close to body of revolution; its surface smooth, elastic, easily deforming (Fig. 1c). Special feature of the cephalopods - presence of specific, rarely encountered in nature, hydrojet motion, according to the operating principle of similar to the fluctuating jet. Sampling and ejection of water occurs periodically (frequency to 5 Hz). Propeller/motor is utilized as the forcing ¹, since it makes it possible to short-term develop speed to 25 m/s.

FOOTNOTE ¹. Usually mollusks move slowly with the aid of two large diamond-shaped fins, which have oscillations in the form of the traveling wave. During the motion with high speed with the aid of reactive propeller/motor these fins "fall" into the special "bays" flush with the body. ENDFOOTNOTE.

The rotating jet of propeller/motor and fins serve as controls.

Analysis of exterior forms of high-speed fishes and marine animals gives possibility to establish dependence of their hydrodynamic characteristics and states of motion, defined by this

generalized parameter as Reynolds number ¹.

FOOTNOTE ². Reynolds number is equal to quotient of the division of the product of the length of body and speed into the kinematic modulus of viscosity of water. ENDFOOTNOTE.

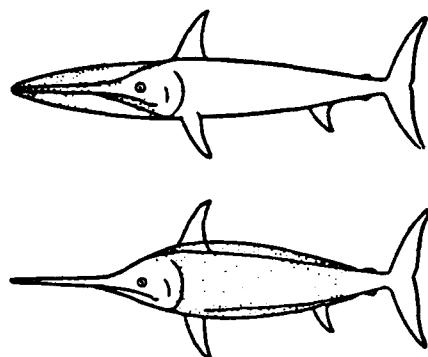


Fig. 2. Two hypothetical variants of cavity, which appears during motion of swordfish at a high speed.

Page 35.

It is known from general solutions of hydrodynamics that roughness of solid surface, especially in its nose section, contributes to transition of laminar flow into turbulent. In the majority of marine animals and fishes in their nose section of such inequalities much; however, the stream-line conditions of streamline in them is retained on larger half of the length of hull. In particular, in the hydrodynamic aspect sword-fish is of definite interest. Its maximum speed, judging from the fact, that it overtakes very high-speed fishes, is equal to 30-35 m/s. On this basis some researchers assume the formation in it of the cavitation cavity, which appears on the tip of "sword" and covering the forward section of the body, and others - its onset in the head part (Fig. 2).

During motion of ship effect of hull on wake current is partially compensated by effect of screw propeller. A similar compensation, but

that more advanced, probably, occurs also during the motion of marine animals, since, for example, after the porpoises it is impossible to detect wake current (wake trace).

Oscillatory motions of body in fishes are well known, but propulsive characteristics of their motion are studied insufficiently. They thus far are established either by the evaluation of muscular energy taking into account metabolism or by using the results of the analytical solutions of the problem of hydrodynamics about the motion of solid bodies in the fluid.

Were recently proposed several designs of propellers, to a certain degree of fish imitating propellers/motors. One of them, that reproduces the traveling wave on the hull, is given in Fig. 3.

In foreign press is widely discussed question about possibility of noticeable reduction in resistance to motion of torpedoes and submarines by introduction into body part of boundary layer (in skin) of liquid, according to its properties of analogous mucus, isolated by skins of fishes. Specialists developed several types of synthetic mucus, are proposed different structural solutions for its introduction, experimental investigations are carried out. However, there is no unified opinion about the rationality of the introduction of this lubrication as yet, although sometimes it gave effect.

Energy calculation of quasi-stationary motion of water animals,

carried out by S. V. Pershin, shows that stream-line conditions in boundary layer is retained virtually in all water animals. In high-speed porpoises and mermas length to 2-3 m the most economical conditions of streamline is retained even at the averaged maximum speed of their motion in 15-25 m/s, when critical Reynolds number for the transition of stream-line conditions into the turbulent reaches more than 10^7 , i.e., many times more than for the case of the longitudinal flow around solid smooth flat plate. By this is partially explained one of the mysterious phenomena - ability of porpoises to reach high speeds during the development of a comparatively low power (about 1.50-2.0 hp).

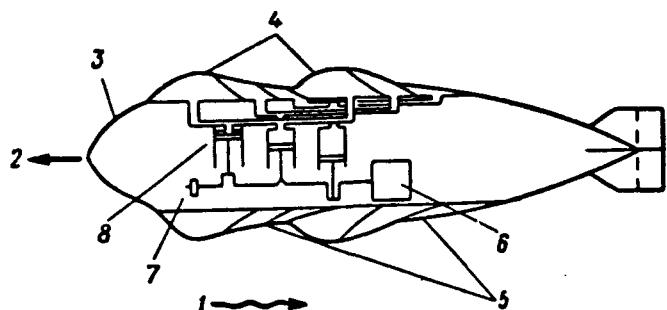


Fig. 3. Propulsive system of ship propeller: 1 - direction of motion of traveling wave on hull of ship; 2 - direction of motion of ship; 3 - rigid hull with openings in cavity of soft membrane; 4 - elastic annular recesses, filled with fluid; 5 - empty cavities of membrane; 6 - engine; 7 - crankshaft; 8 - pumps.

Page 36.

Not is less mysterious another property of porpoises - large specific power output of muscular system of living engines, especially in short-term (pulse) conditions. Analysis shows that for the extreme cases of the duration of motion, for example 0.5 s. and 10⁵ s., the power of muscular energy changes approximately 30 times. It proves to be with the conversion to the power-weight ratio ¹ generally accepted in the ship building that, for example, in porpoises during the conditions of prolonged cruising is equal to 0.2-0.3 hp/t, while with the short-term reaches 8-10 hp/t, i.e., it substantially exceeds the value of the power-weight ratio of contemporary submarines.

FOOTNOTE ¹. By power-weight ratio is understood the ratio of the total power of engines to the total solid displacement. ENDFOOTNOTE.

Such large mobility of muscles of porpoises in complex with hydrodynamic special features of structure of body and fins makes it possible for them to realize acceleration from "stop" before "complete course" (or inhibition) for fractions of a second (approximately in 0.5 s.). They sharply change direction of motion in the horizontal plane: the relative diameter of circulation reaches in them altogether is only 0.5-1.0 of length of body, while in the submarines of the USA it is an order more.

Degree of perfection of hydrodynamic complex (hull - propeller - plumage - muscular system) of porpoise is sufficiently great. Four extremely strongly developed groups of the muscles of its body are fastened with powerful tendons to the upper and lower sides of caudal fin. They provide the specific displacements of tail in the vertical plane and vertical-wavelike motions of entire body. In this case the maneuvers in the "course" and the "depth", inaccessible for the contemporary ships on the speed of performance, are realized with the aid of the same fin by an one-sided contraction of the muscles. The paired antagonistic system of muscular engine-propeller, in which with the elongation of some muscles others are reduced, the absence of turning and twisting of muscular filaments, the close connection of their work with the vital rhythm, the cyclic recurrence of the processes of respiration and blood circulation, coincidence in one muscular mechanism of engine and propeller/motor - all this contributes to the most effective release of energy, to an increase in

efficiency in entire complex and reliability of its operation.

However, description and analysis of exterior forms cannot reveal physical essence, mechanism of phenomena, since they have sufficiently complex nature (so, some organs fulfill functions not only of propeller/motor, but also regulators of buoyancy and means of control). Therefore during the evaluation of organs all made by them functions must be taken in the attention.

Development of surrounding circumstances in aqueous medium, as noted above, the second direction of hydro-bionics.

Page 37.

One of problems of contemporary ship building is considered, as is known, decrease of noisiness of ships and vessels. Basic sources of noise - work of mechanisms and screw propellers, and also the flow around hull. Hydro-bionics can aid resolution of this problem. Whales, as some researchers assert, move in water noiselessly. There is no precise data on the noise formation and its level during the motion of fishes with a speed of more than 30 knots, but there is an opinion that the upper limit of noiseless velocities in marine animals is considerably higher than, for example, in submarines. Power plant and propeller complex of fishes and some marine animals in this respect can serve as sample for the technical development and the application in the ship building. Propulsive propeller mentioned above, which, in the opinion of specialists, must be effective,

noiseless and create minimum wake trace, is one of them. At the same time marine animals are easily detected with echo ranging. Thus, in the Second World War the surface ships of the countries of anti-Hitlerite coalition detected, attacked and destroyed more than hundred whales, accepted as German submarines. During the studies of the antisubmarine forces of Navy of the USA already in the postwar years had false hydroacoustic contacts with the underwater objects reaching 89%. This forced, in particular, on the submarines of the type "Thresher" - "Sturgeon" under the hydroacoustic equipment to lead entire forward tip and establishment of supplementary sound locating stations for the classification of contacts.

In spite of great achievements of science and technology, natural sonars much exceed both on distance and on accuracy contemporary hydroacoustic instruments. For example, because of the large range of the sounds, published with the location, porpoises freely determine not only position of objects, but also obtain all their fundamental characteristics. However, the powers of radiation and the overall sizes of contemporary ship locators are simply incomparable with appropriate data of the organs of porpoises.

In process of search one of species of porpoises - afaline [?], for example, produces rocking with head right-left, approximately 10° , which makes it possible to assume directed sound emission in porpoises. Investigations show that the radiation pattern of auditory signals in them is most narrow at the high frequencies. The ear of

porpoise is well adapted to the perception of the unusually large range of the sound vibrations: from 150 Hz to 150 kHz. In connection with this the importance of auditory analyzer is obvious.

Investigations in region of orienting of marine animals and identification of modes can prove to be very promising. In particular, the study of the collateral line of fishes as the organ, which receives the electric currents, which are spread in water, opens the prospects for the creation of instruments for the reception of infrasounds (1-25 Hz), and also perhaps electrical and magnetic fields. Even now it is established that on the sensitivity to the electric field fish occupy the first place among the living organisms.

Riddle thus far remains ability of eyes of porpoise to retain identical visual acuity, also, in water and in air. Its solution would make it possible substantially to improve many instruments, adaptations and devices, utilized by underwater swimmers, also, on the ships and the vessels. It is at present known that porpoises, being found in water, can select place and match the force of jump in order to reach and cover small objects, which are found 4-5 m above the surface of water.

Page 38.

Mechanism of smell is still very little studied, but it is established that some biological species react to unit aromatic molecules '.

FOOTNOTE¹. For greater detail, see M. S. Chizhov's article "Instruments - on the licenses of nature" ("Marine Herald", 1966, No. 2). ENDFOOTNOTE.

It is obvious that the results of the investigations, connected with the development by the representatives of the living world of the surrounding circumstances, the detections by them of visually invisible targets, deviation from them or attack on them can render essential assistance in the creation of analogous technical devices.

Principles of functional activity of nerve network of organisms, which live in aqueous medium and methods of processing by them information are following direction of hydro-bionics. Works in this field can prove to be highly useful during the creation of the new systems for control and monitoring/checking. More than that, it is considered that the joint investigations of engineers and neurophysiologists will lead to further development of the science about control and to the appearance of managers of fundamentally new type systems. Hydro-bionics, in particular, will be able to aid in the resolution of such problems as:

- storage and processing large quantity of information;
- an increase in the reliability of the electron systems, which consist of the less reliable elements;
- the creation of electronic computers for solving the problem without the preliminary programming, and also self-adapting systems;

further miniaturization and the super-miniaturization of elements and blocks of electronic equipment, etc.

This enumeration is not comprehensive, but also makes it possible to present possibilities, which are disclosed during use of achievements of hydro-bionics in technology. Even now it is known that the "density" of the neurons of the brain of porpoise (close to the density of the neurons of the brain person) is equal to approximately 10^8 in 1 cm³, and in the best technical schemes is reached the "density" of parts only 10^3 in 1 cm³. Moreover the complex nervous system of porpoise, which consists of the large number of neurons with the relatively low reliability, as a whole is very reliable. It without interruption functions for several years, while most complex contemporary electron systems work incomparably shorter time without the replacement of separate elements or blocks.

Deep-water immersions - specific direction of hydro-bionics.

Until now ability of some cetaceous to dive to depths to 2000 m causes surprise, testing pressure to 200 atm. and actively move for one-and-a-half hours without replacement of air in lungs. Therefore the biology of these animals is of great interest for the resolution of the problem of the deep-water immersion of man ².

FOOTNOTE ². Descent of G. Keller in 1962 without the severe pressure suit at the depth of 338 m is thus far accepted abroad as record, at

which fulfilled the assigned volume of works. ENDFOOTNOTE.

At present investigations in this direction are conducted in France, USA, England and other countries. Already it was possible to explain the basic points of the mechanism of the safety of rapid immersion and lift to the surface of cetaceous, the reason for nonsusceptibility of their "caisson illness" - these are the result of the absence of respiration for the time of the immersion (use of one "portion" of air), the presence of a vast quantity of hemoglobin in the muscles, the reduced sensitivity of the brain and respiratory centers to the accumulation in the blood of carbonic acid, a good protection by adipose tissue from chilling.

Page 39.

Study of special features of biochemical metabolism in marine animals, investigation of ways of their reproduction in organism of man and connecting with his vital activity - here is way of mastery by humanity of ocean depths, available now only to cetaceous.

Service of hydro-bionics to interests of fleet is not limited to enumerated directions. Its interesting and peculiar region - the collaboration of some marine animals and man. There are known many cases, when porpoises "voluntarily" rendered aid to people, which suffer distress in the sea. In them large capabilities for instruction and even tendency toward the demonstration of intricate and even special tricks in oceanarium. This makes it possible to hope

for their successful enlistment to conducting of underwater investigations. Thus, are specialists of Hawaiian university (USA), achieved high results in training of afalin under the conditions of the open basins, they intend to utilize animals for obtaining the information about the behavior of oceanic inhabitants and for accomplishing different actions under the management of man. In particular, porpoises have already been utilized as the messengers, who ensure the work of divers. It is natural that the circle of the problems, laid on the specially trained porpoises, can be substantially expanded.

Recognizing importance of possible results of investigations on hydro-bionics and, first of all, their use for improving naval technology, scientists abroad, especially American, perform great special work to assignments of Navy, create hydro-biological stations, are improved and constructed different types of oceanariums, basins and aquariums. Today in the USA function about ten (without considering the closed specialized stations). In Japan also there are basins fenced in by networks of inlets for the work with the porpoises.

For investigations, connected with mastery by man of large depths, and instructions of porpoises to serve people, are created special underwater constructions.

Probably, within the next few years work on hydro-bionics will

leave in framework of laboratory investigations and results of studying of marine animals and fishes will help man to find ways for new noticeable jump in improvement of marine technology and mastery of world ocean.

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